Project Review of the Advanced Light Source Ultrafast X-ray Science Research Project Review

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LBID-2465

Review Scope and Charge

The management of the Advanced Light Source asked the LBNL Integrated Project Management Office to conduct a review of the Ultrafast X-ray Science Facility (Femtoslicing) research project. The review was conducted on March 25 and 26, 2003. The members of the review committee are listed in Appendix A. The agenda of the review is included in Appendix B. The Femtoslicing project has received its funding and has been actively planning, exploring options, and pursuing design work for the project. The Femtoslicing research project employs a femtosecond laser beam to interact resonantly (free-electron interaction) with the electron beam in the ALS. The induced energy spread over the femtosecond duration is converted to a transverse displacement by exploiting the dispersion of the storage ring. The displaced femtosecond electron pulse then radiates and produces femtosecond synchrotron radiation.

In order to optimize the research configuration, the experimental program requires a new 11-cm permanent magnet wiggler (W11) in Straight Section 5 for e-beam modulation, (subject of a previous review), a new radiating undulator (either superconducting or in-vacuum permanent magnet), an upgraded high power femtosecond pulsed laser system, and a new beamline. All of these systems, with the exception of the W11, were the subject of this review.

This review was to assess the proposed approach, organization, budget schedule and quality being pursued in the execution of this research project.

The review committee was asked to assess during the review the overall preparedness of the research project team and consider the following questions. The Committee's responses follow each question.

Q1: Is the project organized so that ALS and LBNL management may have a reasonable expectation that the commissioning and scientific research will begin when anticipated?

A1: In general yes, but funding profiles, projected liens vs. actual costs and specific budget and schedule details require additional clarification.

Q2: Are those points where ALS management needs to provide input clearly identified?

A2: For the insertion device selection the input points are clearly identified. Bridge funding and total funding scenarios should be discussed sooner rather than later with ALS management. The ALS upgrade implications on the approach of the project and ultimate performance also require discussion with ALS management sooner rather than later to avoid adversely impacting the project.

Q3: Have any additional resources, external to the project, but needed for ultimate scientific success, been clearly identified?

A3: Yes. Additional details concerning this question may be found in the comments of the individual technology areas.

Q4: Are all the proposed project and development plans with options reasonable in scope, budget and schedule?

A4: The initial contingency level is likely too small and additional scope contingency development and the risk analysis and management must be completed.

Q5: Have the trades, constraints, risks and decision points been clearly identified for all systems?

A5: At the time of the review, the tradeoffs concerning project scope versus funding and phasing require further definition.

Q6: Are the proposed budgets adequate and reasonable enough to allow the project to achieve its technical objectives?

A6: The proposed budget options appear reasonable and will allow the project to achieve its technical objectives provided that ALS and LBNL management agree to the necessary bridge funding liens and obligations. This bridge funding to cover liens and obligations is necessary to allow the project to mitigate existing funding profile shortfalls. However, as previously noted, the contingency levels appear light.

Q7: Is the proposed schedule for each of the major systems reasonable and achievable in the context of the overall activities of the project and the competing demands of its personnel at ALS?

A7: The limited resources and the technological issues associated with the laser system remain a cause for concern (see specific comments under Laser System). Also, it would be advantageous to the project to accelerate the placement of the order for the in-vacuum undulator. Valuable commissioning time could thereby be gained while running in parallel to the final stages of laser system development.

Q8: Are the development approaches to each major subsystem – laser, undulator, and beamline – appropriate and technically sound?

A8: Yes, subject to comments within the specific technical sections.

Q9: Have the impacts on the ALS ring and beam dynamics been adequately addressed?

A9: Yes, subject to comments within the specific technical sections.

Q10: Are there any areas or issues that have not been adequately addressed or clearly identified?

A10: See specific section comments. It will likely be necessary to reconsider trades concerning first phase capabilities such as: between hard x-ray and soft x-ray, and initial repetition rate. Clearly identifying scope contingency and alternative project phasing schemes to accommodate funding profiles and budget pressure is required.

General comments:

The overall development of the project appears to be very good with careful consideration being paid to all options and issues that have been identified. The project team is extremely competent and appears to be working well together.

A change in the development schedule has been necessitated because of the delay of the funding from DOE. The DOE provided profile clearly is not compatible with a 3-year program. It is important that ALS and LBNL attempt to find ways of meeting the funding profile in order to maintain a satisfactory schedule. There is a shortfall both in funding profile (of order ~$1000k across a fiscal year boundry) and in total magnitude (~$700k). However, given the scientific competition, it is highly desirable to meet a 3-year completion for the project and an early start of the hard x-ray beamline.

The project team presented a reduced scope option that requires suspending the current scientific research program and delays increase of the laser repetition frequency from 20 kHz to 40 kHz.

The project has gotten off to a good start on overall risk management, but it needs to be completed and incorporated down to the lower subsystem levels including an evaluation of equivalent technology readiness levels and the specific contingency evaluation. In general a 20% contingency level for a project with a large number of R&D issues is considered too small. As there are significant schedule and budget constraints, additional scope contingency will likely be necessary.

Specific technical area comments:

Beam Dynamics

The storage ring physics analysis done to date is very comprehensive and well thought out. The vertical dispersion bump has been well characterized and shown to be feasible. An important issue is, as presently conceived, the vertical dispersion bump and the insertion device magnetic fields produce an increased vertical emittance of order 80 pm. This is significant when considering the reduction of the vertical emittance being discussed as an ALS upgrade.

There still is work to be completed in order to prove the suitability of the 5 mm gap within the ALS by July. There has been a detailed study of the 5 mm gap, but it has only started to include the effects of the dispersion bump, which may impact the dynamic aperture and beam lifetime. Tracking and machine studies to refine the configuration are planned and the project has a clear idea of how to proceed. There is the ability to perform machine studies with a dispersion bump located coincident to the scrapers presently on ALS, and this will give both good benchmark of models and operational experience. Although the dispersion bump is an issue that requires investigation it seems quite straightforward.

The drive to improve the signal to noise (S/N) ratio of the femtosecond x-rays will require reducing the scattering from the mirror. This combined with the ALS upgrades as presently conceived will tend to drive the dispersion bump to smaller values. One should note, however that the drive to ultra low emittance in ALS for the upgrades has not been fully assessed and with the proposed lower emittance many beamlines will likely be diffraction limited. Consequently, they would not be able to exploit the dramatically smaller emittance.

The Committee recommends placing the insertion device at the front of the straight section. This option would allow the possibility on an EPU to subsequently be placed in the straight section. The interest and scientific case is growing for such a capability. BESSY includes such an EPU and so maintaining this option will provide a source with more ultimate flexibility.

Insertion Device

The project presented both an in vacuum permanent magnet insertion device (IVID) option and a superconducting insertion device (SCID) with intermediate temperature (~20K) vacuum bore. Apparently, in the initial scooping of the project, it was believed that only a SCID could meet the project requirements. With additional development, the IVID has been shown to be able to meet source requirements as well.

The SCID point design that meets the project requirements does not push superconducting technology limits as hard as many other proposed SCIDs. The vacuum chamber aperture is larger and has a 20K vacuum bore temperature that allows the use of larger capacity cryocoolers to dissipate heat deposited on the chamber walls within the device. The point design is only at 80% of a conservative critical current density J_c for the typical NbTi conductor. The SCID option, as presented, would delay start of any science by 9 months (Jan 2005 – Sept 2005), and requires an additional $580k ($220k without research and development).

The IVID point design is based on published and transmitted data from Sumitomo. It uses a vacuum aperture of 5 mm and a material choice based on the largest available residual induction (B_r) consistent with resistance to thermal and radiation demagnetization (requiring typically a large intrinsic coercivity). The IVID procurement is more straightforward and has inherently less schedule risk than the SCID. The IVID has a relatively low design margin for the magnetic field. However, this small design margin isn't a major concern as the supplier (Sumitomo) that provided the information is generally quite conservative. The vacuum RF transition sections still require some clarification and attention.

Insertion Device Recommendation:

The decision between the two options clearly rests with ALS Management. However, in considering the two insertion device options, the Committee feels that the reduction in risk to the project merits pursuing the IVID as the main approach. The IVID has a strong supplier with a well-established track record and delivery history. The same cannot be said for the SCID at this time.

The SCID design approach appears sound and conservative. Demands on peak field, field quality, and heat loads are very reasonable. Consequently, the Committee feels much of the R&D presented as part of the SCID option would not be required allowing the earlier placement of an order thereby reducing some schedule risk.

Beamline

The beamline schedule is realistic if the project team remains focused on the project.

There should be some consideration to increasing the R&D investment in the mirror scattering program. There should be both a performance goal and a clear time limit established when the final order is placed so that the commencement of beamline commissioning is not compromised.

The team is to be commended in its approach to re-using a significant number of commercial and previously deployed designs and components.

The Committee recommends that the project team explore ways of sharing development and risk of the 40 kHz chopper with the supplier. There are likely strong commercial benefits for the supplier to have demonstrated a device with such high-speed rotation and therefore it has an additional incentive to be successful.

The Committee views the chopper lifetime as an area of considerable risk. Typically, in order to establish a system lifetime the operation of a prototype unit continues until failure. With only one chopper this is somewhat problematic. Although the supplier should be able to provide some lifetime analysis, the supplier has not actually operated devices as such an elevated frequency. One option, especially in view of the delay in increasing operation at 40 kHz, is to operate the chopper at a reduced frequency for a period of time. This should mitigate some of the risk of the short lifetime while working toward providing a spare chopper from the operations budget. Nonetheless, the Committee feels that including a spare chopper within the reduced scope option would be prudent. In all cases it appears that the spare chopper will have to be covered by the operational costs of the beamline.

An attempt should be made to maintain a future upgrade option of having two simultaneously operating beamlines (hard and soft x-ray) for the ultimate configuration with two insertion devices (IVID and EPU) present in the straight section.

Concerning having both hard and soft x-ray capabilities, the Committee feels that as a result of budget and funding profile issues staging one capability in significantly in advance of the other will need to be considered. The aspect of the choosing only one wavelength range may limit the immediate scientific research options for this project, but budgetary constraints may leave no other option. From the information presented, if one of the beamline capabilities is required for scope contingency, the Committee feels that the soft x-ray appears to be the more likely candidate for delay. The order of priority between the hard and soft x-ray should be carefully examined and conducted in the context of a global optimization.

Laser System

The laser system and development plan is generally well thought out, with many aspects and issues being correctly addressed (analysis of make versus buy, optical setup, heating and cooling analysis, and gain analysis). There is a strong use of existing knowledge collected with operating experience on the current system, and this promises an edge relative to competition., Some key component tests are still missing and require development. The integration of the laser system into ALS infrastructure appears quite clean and straightforward. ALS facility and engineering support (in areas such as cryogenic-chamber, electronics) appears adequate.

The requirement for synchronization of better than 100 fs is not immediately straightforward for such a complex chain of subsystems as are being proposed. In particular, the requirement of stability to better than 1 micron in the delay unit may be quite challenging, particularly if the vibrations of the nearby cryocooler are not well damped. The design of the delay unit components will be critical as well, and care must be exercised to avoid potentially disastrous mechanical resonances.

There are three areas of specific comments:

- Damage risk has not been evaluated to a full extent (e.g., crystal surfaces, dichroic mirrors, AR coated windows). Additional monitoring of the system over time to permit the early detection of the onset of degradation is considered important. It may be advisable to include consideration of a design without the AR coating in the cryo-cooled optics. Coated optics in vacuum transmitting high-fluence green pump beams may degrade over time.
- The timing of the purchase components and the inherent possibility of delays is an issue. Clearly, the schedule is resource limited and is, or near, critical path and this results in a serial, sequential-only, scheduling that may easily become a serious issue. Consequently 1.2 full time equivalents (FTEs) may not be sufficient to ensure timely completion of the laser system.
- Additional testing and exploration of additional parameter space, e.g. gain modeling with different parameters of pumping and polarization situations, is encouraged.

There are two key components to evaluate before purchasing:

- The grating where the issues surrounding it are mostly technical in nature.
- The pump lasers where the issues surrounding it are mainly market and supplier condition (Coherent/Positive Light).

Laser System Recommendations:

The Committee recommends that the project obtain an indication as soon as possible from Coherent as to which of the two pump laser product lines (Coherent or Positive Light) will become the principal product line with continued development and support, and that such information be carefully considered in the choice of a pump laser system.

A flow-down analysis of the pointing stability requirements should be done, both from the spatial overlap requirement in the interaction region, and from the temporal stability requirement. Spatial pointing instabilities can transform into temporal instabilities, especially in the pulse compressors and delay line.

Consider alternate designs that do not require pumping (green) through a polarizer or quarter-waveplate. Consider also alternate designs that do not require any AR coated optics in the vacuum vessel.

The project should consider a lump package purchase of the optical elements, and mounts to reduce procurement and total costs.

In the area of simulations, the Committee recommends more gain studies exploring different parameters such as pumping level, temperature-dependent sigma, and B integral evolution during laser beam propagation.

Evaluate potential thermal problems in high-average-power use of Pockels cells for switching green pumps. Consider designs that do not require Pockels cells.

The Risk analysis for critical components must be completed in detail in order to fully understand operational reliability and availability.

Allow in the design at this time the space and ability for future enhancements to allow active pointing and control of lasers.

The project should consider a single grating for the two compressors.

Appendix A: Review Committee Members

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Appendix B: Review Agenda

Ultrafast X-ray Science Facility Review

Tues. March 25

ALS Building 6-2202

Agenda:

8:30 am	continental breakfast	
9:00	Executive Session	
9:30	Robert Schoenlein	Scientific Motivation Background – Generation of Femtosecond X-rays Technical Overview and Specifications
10:30	break	
10:45	Alan Paterson	Project Management Overview of Project Plan scope, budget, schedule, and risks
11:30	Christoph Steier Weishi Wan Christoph Steier	Accelerator Issues – Vertical Dispersion Bump Accelerator Issues – Insertion Device
12:45	lunch	
1:45	Steve Marks (Ross Schlueter)	Insertion Device - performance requirements - technical issues and risks - project plan (scope, cost, schedule, staged schedule)
2:45	break	
3:00	Phil Heimann	Beamline - performance requirements - design
3:45	Rob Duarte	Beamline - technical issues and risks - project plan (scope, cost, schedule, reduced scope)

Ultrafast X-ray Science Facility Review

Wed. March 26
ALS Building 6-2202

Agenda:

8:00 am	continental breakfast	
8:30	Executive Session	
9:00	Russell Wilcox	Laser System - performance requirements - technical issues and risks - design
10:30	break	
10:45	Russell Wilcox	Laser System - design - project plan (scope, cost, schedule, reduced scope)
11:30	lunch	
12:00	Breakout Discussions (working lunch)	
	(6-2202)	Insertion Device and Accelerator Issues
	(2-400F)	Beamline, Mirror Scattering (talk by Malcolm Howells)
	(6-1105)	Laser System
1:45	Break	
2:00	Schoenlein/Paterson	Summary – Overall Project Plan Next Steps in Project Development
2:30	Executive Session	
4:30	Closeout	